Implementing Resource Scheduling Techniques

A Guide for
Planners and Scheduler's

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INTRODUCTION

When dealing with complex projects, the problem of establishing good operational schedules and effective utilisation of resources is acute as well as difficult and frequently occupies a great deal of senior management time. It is in this sphere of operations that the economic benefits to be derived from the use of a resource scheduling programme and the computer can be truly significant. In recent years more and more businesses and government departments have turned to the planning of projects using Critical Path Network planning software tools, to produce the desired results.

However in spite of the gains made in the management of projects it has in the main been limited to managing time and budget and the management of resources has been seen to be too hard or not my problem, we use sub contractors.

For small comparatively simple projects, time schedules can be estimated manually; but for more complex projects manual methods are too time consuming and costly. It is not practical in any organisation to consider projects in isolation as independent entities as there is often a relationship between projects due to their schedule and workload, resources and costs must be taken into consideration as well. Not only that, but the inter-relationship one project may have on another must be observed. To try and calculate the solutions that may be applicable manually is obviously out of the question. Therefore to be able to schedule effectively and easily, the use of a computer and suitable software application provides an ideal solution.

Network planning, better known as PERT (Program Evaluation and Review Techniques) or CPM (Critical Path Method) is a management technique for planning, scheduling and controlling one or several projects. Over the years many systems with these features have been developed, but they all have one thing in common; they use a network either in Arrow Diagram or Precedence Diagram format such as Micro Planner X-Pert for Windows, or Gantt chart format, such as Primavera, Open Plan and Microsoft Project. Micro Planner X-Pert is one of the few that can use Arrow and Precedence Diagram format. The network diagram or logic diagram as it also known is the only way to clearly show the logical sequence of tasks/activities which must occur before a project can be completed. The benefits to any organisation implementing network planning are shown below:-

- Plan Projects in the required amount of detail
- Ensure that target dates are met by establishing improved work schedules
- Make more effective use of resources
- Establish realistic budgets
- Measure the effect of one project upon another
- Simulate the effect of different decisions before firm policies are laid down
- Highlight activities requiring special attention
- Forecast potential bottlenecks
- Monitor progress and highlight delays in time for corrective action
- Monitor expenditure by measuring estimated costs against actual costs and the value of work completed
- Achieve better co-operation between work groups

WHAT IS A NETWORK?

The classical definition of a network is stated below:-

"a network is a pictorial representation of a project plan, indicating the inter-relationships and   inter-dependencies of the component tasks"

Networks are also known as either Arrow Diagrams or Precedence Diagrams; however the term network is more commonly used and will be used throughout this handbook. An Arrow network consists of two basic elements, these are:-

a) An activity, this is usually represented by a straight line or arrow and indicates a complete job
b) An event, these are usually represented by either a circle, or square and indicate the beginning and ending of an activity

A Precedence network consists of two basic elements, these are:-

a) A task, this is usually represented by a rectangular box an indicates a complete job
b) A link, this is usually represented by a line connecting the finish and the start of a task; there are four types of link, these are:
- Finish to Start
- Start to Start
- Finish to Finish
- Start to Finish

Activities (or Tasks) are considered to be time and resource consuming, events are not, and they merely represent some specific point in time. A link is used to logically connect two tasks and generally do not consume time. However where required a duration may be placed on a link. Figure 1 below is a simple Arrow Diagram showing the relationship of different activities of a design project. All relevant activities and events are included, though the depth of detail can vary from project to project requirements
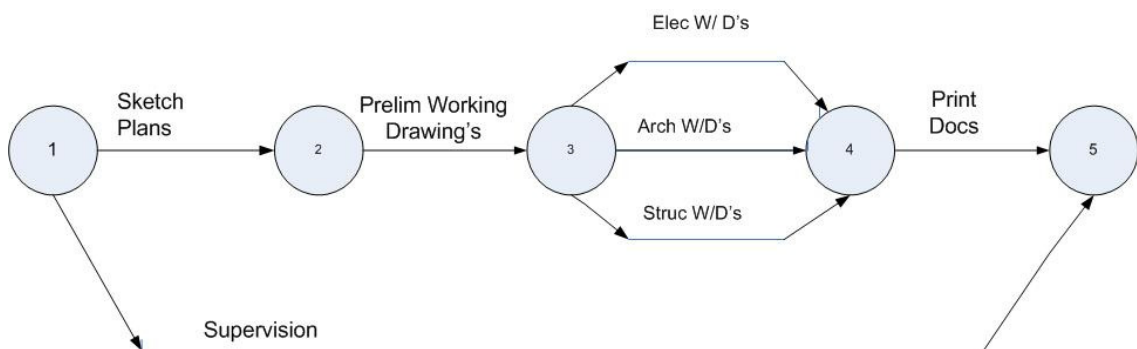

Figure 1: Arrow Diagram

The alternative format is the precedence diagram; Figure 2 below shows the same information and logic as Figure 1.
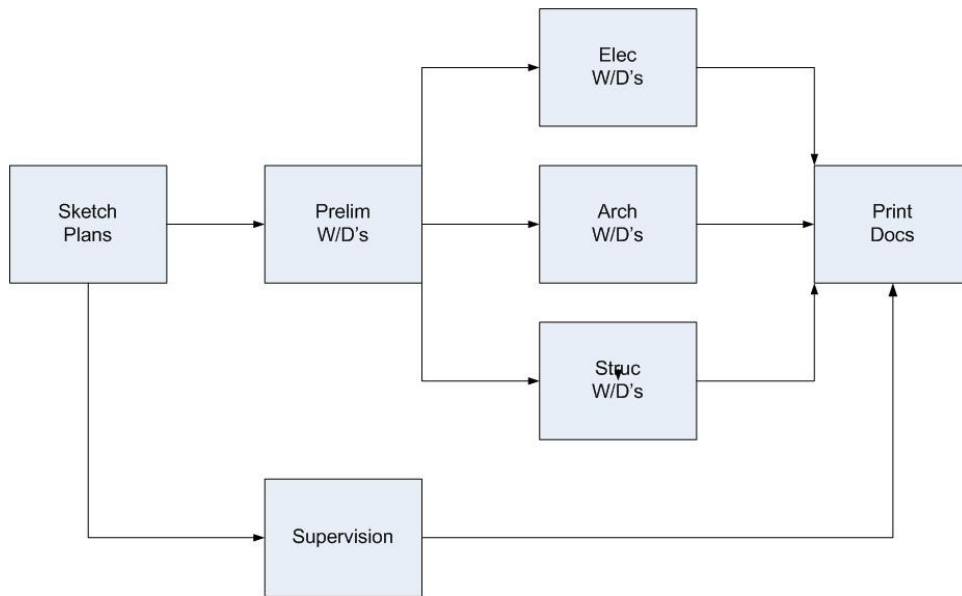

Figure 2 Precedence Diagram

The preparation of the network is best carried out by a group made up of those people directly concerned with the execution of the project. This personal involvement at all stages, of various work groups helps avoid ambiguities and misunderstandings in the plan.

TIME ESTIMATES

Once a network has been drawn up and the details agreed to by all interested parties, time estimates must be assigned to each activity (task) to carry out time analysis. This establishes the length of the project and pinpoints the activities whose aggregate times constitute the longest path through the network. This is known as the Critical Path, since it is longest path in the network. It is then, the shortest time that the project can be accomplished in.

In most industrial and commercial applications, single time estimates are used for each activity (task). A single time estimate is where if a particular activity was repeated many times the same or similar time would be taken to execute that activity. The single time estimate is also known as the most likely time. As these are usually supplied by people responsible for carrying out the activities they represent the best time estimates for the work involved.

As soon as all the activities have been timed, the data is drawn or entered directly into a suitable project management software application such as Micro Planner X-Pert for Windows. After the first analysis, the time estimates and logic of the network often need to be reviewed as the results may not meet contractual expectations.
The Management and / or Contractual targets may not be feasible and thus effort must be concentrated on the critical path itself to reduce the time required, of course not forgetting

any sub-critical paths with float up to amount of time you are trying to reduce, thereby meeting these impositions.

For some projects, particularly in the new areas of design it is not always practicable to provide a single time estimate for certain activities or tasks, due to the inherent uncertainty associated with this kind of work. To overcome this three-time estimates (which were invented for the Polaris project in 1956 and created the PERT technique) are available in some software. Micro Planner X-Pert for Windows allows the specification of three time estimates or as it is currently known in 2008; three Point Estimates. The three times are known as

a)   Pessimistic Time Estimate; time to complete an activity under adverse circumstances
        Usually a one chance in hundred
  b)   Most Likely Time Estimate: time to complete an activity under normal conditions.
        Usually 98 in a hundred
Optimistic Time Estimate: time to complete an activity if everything goes exceptionally well.
        Usually a one chance in a hundred

The three time estimate is computed using the beta distribution formula as follows:-

$$\frac{A + 4b + c}{6} = \text{Expected Time}$$

Where a = pessimistic time
        b = most likely time
        c = optimistic time

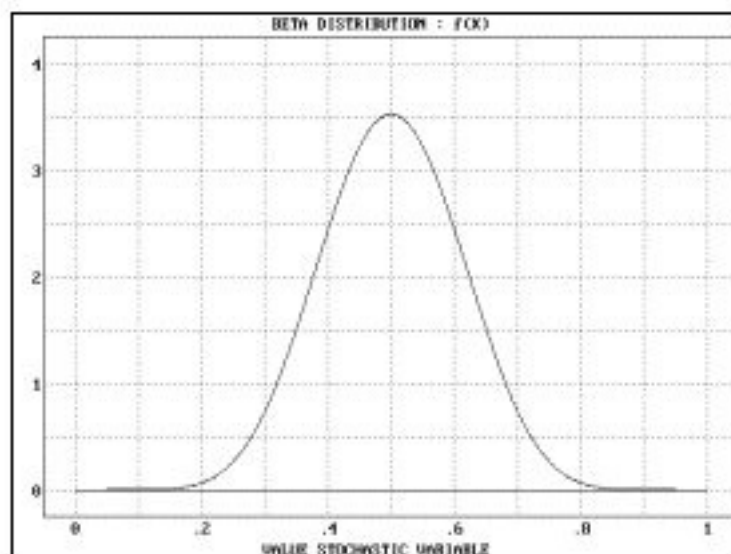The figure below shows a "normal" beta distribution curve

The beta distribution curve will be skewed either left or right depending on the estimated times. This provides a statistically weighted average. Micro Planner X-Pert for Windows as well as other software programmes allows the time to be estimated in various size units. For example "Weeks, Days and Hours", Weeks and Days", "Days and Hours", and Hours and Minutes" or just plain days

TIME ANALYSIS

The actual calculations carried out by the software to produce the Critical Path are known as Time Analysis. All the data contained on the network is either entered into the software directly by either drawing the network as in the case of Micro Planner X-Pert for Windows, or in Gantt chart format as in Microsoft Project or Primavera. The Time Analysis process is carried out in two parts; these are known as the forward pass and the backward pass. The forward pass calculates the Earliest Start and Earliest Finish Dates for all the Activities / Task and Events. The backward pass calculates the Latest Start and Latest Finish and the Float values for each Activity /Task and Events.
There are four float values which can be computed, these are as follows:-

- Total Float
- Early Free Float
- Late Free Float
- Independent Float

However not all software applications actually calculate all these floats, most will produce Total Float and Free Float (which generally is actually Early Free Float) as the value is calculated by the forward pass. Float is the amount of time by which an activity / task can exceed its' specified duration without endangering the completion date of the project.

Having run the Time Analysis and prior to running Resource Analysis, it is a good practice to produce various reports which indicate the results of the analysis. The sorts of reports are as follows -

- Milestone Reports showing the dates that each milestone has been scheduled to either start or finish.
- Activities /task listed by Total Float, this is a list of all the activities in the network sequenced by Total Float. Thus the critical path activities will be shown at the top of the report. Also shown are the earliest and latest start and finish dates for every activity and the amount of total float available
- Activities listed in earliest start, this is a list of all activities in the network sequenced by earliest start date. Therefore a chronological list of activities is produced which enables management to organise the execution of the initial section of the project
- Bar charts in a variety of forms to suit specific requirements, e.g. turnaround documentation for updating.

The following figures illustrate each type of report as defined above.

Figure 4

Project	: 2004040044 A8-134					
Title	: A8-134 Milestone Variation Report					

Date of Report Data : 11-Dec-07
Date Report Printed : 6-Feb-08
Sheet : 1 of 4

Milestone Id	Milestone Description	Baseline Date	Achieved Date	Current Schedule Date	Variance Between Baseline & Current	Comment
AIRCRAFT						
SRT	Start of Aircraft Servicing			11-Dec-07	0:0	
AFT FUSELAGE						
AFT_BGIN	Commence AFT Teardown			11-Dec-07	0:0	
CTR_BGIN	Commence CTR Teardown			11-Dec-07	0:0	
FWD_BGIN	Commence FWD Teardown			11-Dec-07	0:0	
ENDINT		11-Dec-07		11-Dec-07	0:0	
MILESTONE						
PSHOP	Aicraft ready for PAINTSTRIP	22-Jan-08		22-Jan-08	0:0	
OWF_RB	From CTR (Overwing Fairing Rebuild Complete, ready to fit to A/C)	23-Jan-08		23-Jan-08	0:0	
MILESTONE						
A06	Milestone Aircraft Ready for JACK and TRESSEL	13-Feb-08		13-Feb-08	0:0	
MAN_JACK	From MAIN (A/C Jack & Tressel)	13-Feb-08		13-Feb-08	0:0	
MILESTONE						
AFT_TEST	Ready for TEST (AFT Rebuild COMPLETE)	14-Feb-08		14-Feb-08	0:0	
CTRZONE2	From CTR ZONALS Completed #2	18-Feb-08		18-Feb-08	0:0	

Figure 4 Milestone Variation Report

Figure 5

Date	:	6-Feb-08
Time Now	:	18-Dec-07
Project	:	2004040044 A8-134
Output	:	**Activities in Total Float Sequence**
Sheet	:	1 of 17

	Start	Finish	Total Float HH:mm	Budget Hours
MAIN				
PSS				
WP014_LH Wing Removal (S50 Servicing).	15-Jan-08	16-Jan-08	0:0	68.00
WP015_RH Wing Removal (S50 Servicing).	15-Jan-08	16-Jan-08	0:0	68.00
AIRCRAFT				
PSS				
WP002_AC Wash	17-Jan-08	21-Jan-08	0:0	68.00
SURFIN				
Aircraft at Paint Shop for Paintstrip	22-Jan-08	12-Feb-08	0:0	0.00
PSS				
WP012_Aircraft Jacked	13-Feb-08	13-Feb-08	0:0	12.00
CTR FUSELAGE				
NDT				
WP202_CTR Fuselage NDT Inspections	13-Feb-08	17-Mar-08	0:0	366.00
AV_TECH				
WP463 ATECH/AVTECH CTR FUSELAGE MTC PACK	17-Mar-08	10-Jun-08	0:0	2380.00
TEST				
TEST_TEAI				
WP484 DM FUNCTIONALS RECS RNCC PACK	10-Jun-08	23-Jul-08	0:0	1050.00

Figure 5– Activities in Total Float Sequence

Figure 6 Activities Sequenced by Earliest Start

	Start	Finish	Total Float HH:mm	Budget Hours
AIRCRAFT				
RECS				
WP_487 Life Support MTC Pack	11-Dec-07	18-Dec-07	959:40	40.00
CPLT				
WP027_CPLT Preparation (Install Fixtures & Temp fit panels)	11-Dec-07	8-Jan-08	617:40	140.00
PSS				
WP010_Aircraft De Panel Only	11-Dec-07	14-Jan-08	290:0	102.00
AFT FUSELAGE				
PSS				
WP032_LH_Horizontal Stab Removal & Service (WZ 28.0)	11-Dec-07	23-Jan-08	115:40	146.00
WP044_RH_Horizontal Stab Removal & Service (WZ 29.0)	11-Dec-07	23-Jan-08	115:40	146.00
FWD FUSELAGE				
STRUCTURES				
WP465 ASTFITT FWD MTC PACK	11-Dec-07	17-Apr-08	137:40	620.00
AFT FUSELAGE				
STRUCTURES				
WP467 ASTFITT AFT MTC PACK	11-Dec-07	17-Apr-08	137:40	550.00
CTR FUSELAGE				
STRUCTURES				
WP466 ASTFITT CTR MTC PACK	11-Dec-07	8-May-08	47:40	640.00

Figure 7 Turnaround Progress Report

RESOURCE SCHEDULING

Resource scheduling is designed to provide effective work schedules and the efficient utilisation of resources. In the past two years the implementation of resource scheduling has become known as Resource Loading, but has not been as prolific as would be expected. Resource scheduling was quite extensively used during the 1960's until the mid 1990's whilst mainframe Project Management software existed. ICL the well known British computer company produced a very good range of Project Management software which

allowed the user to plan and schedule project plans using many of the features defined in the PMBOK.

For example ICL VME PERT allowed the user to perform Time Analysis, Resource Analysis and Earned Value Performance Measurement and Cost Control in a simple and consistent manner. As PC's became more popular from the end of the 1980's, much of the Project Management software produced provided only basic functions to the user. Some notable exceptions being Micro Planner X-Pert, Plantrac, Harvard Project Manager, Primavera V3.1 and OPP . Even though the Resource Scheduling facility is available in such products as Primavera V3.1 and OPP, many users choose not to use this facility due to not wanting to collect the amount of data required or learn the myriad number of settings required to produce a result.

Not performing Resource Scheduling will lead to inefficient utilisation of resources and increased costs. It is usually neither possible nor expedient to commence activities / tasks in a project at the earliest dates calculated by the time analysis section of the software. The main reason for this is because Time Analysis takes no account of restrictions arising from resource shortages.

The purpose of resource scheduling is to provide a better picture how the project should be executed; this is achieved by scheduling activities where possible between the earliest feasible start date and the latest permissible finish dates. At the same time the software program can take into account conditions and restrictions imposed to meet management and / or Stakeholders requirements. Resources are defined as People, Plant, Products, Machinery and Space. The following data is essential for software to carry out resource scheduling:-

1. The Resource requirement for each activity / task
2. The total amount of each resource available to the project as a whole
3. Any management impositions to be observed during the scheduling process
4. Any Activity / Task property

RESOURCES REQUIRED

The estimated duration of an activity / task normally depends on the resources available. Usually estimates are based on people resources (the time taken by 'n' people to perform a particular task), but other resources, such as plant or materials may be taken into consideration. Micro Planner X-Pert for Windows handles resources in two ways;-

1. Those which are rate-constant, such a people (for example, Tech is required each day for all or part of the activity / task duration
2. Those which are total-constant, such as materials (for example, 500 litres of Paint needed in all) regardless of the duration of the activity / task

If during actual operation, an activity exceeds its estimated duration, a rate constant resource will continue to be allocated beyond the estimated duration at the specified rate, whereas a Total constant resource will not.

Resources are designated either simple or complex if so required. The value of the complex resource is that where a resource is utilised only for certain parts of the activity, this complexity can be stated accurately. Obviously this will produce a much more efficient utilisation of the specific resource in question as it will be available for other activities at the time when it has not been allocated to the particular activity. Alternatively, a resource

can be considered to be simple, that is once it has been allocated to an activity / task it is used continuously for the entire duration.

The benefits of being able to indicate that a resource is either simple or complex is that it enables the network to be less intricate and compact as possible. Figures 7 & 8 illustrate examples of simple and complex resources allocated to an activity / task.
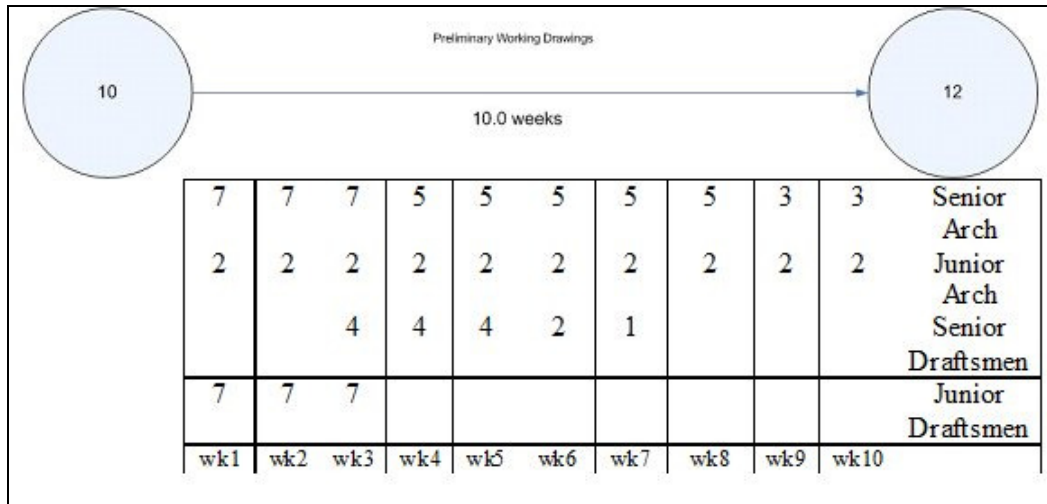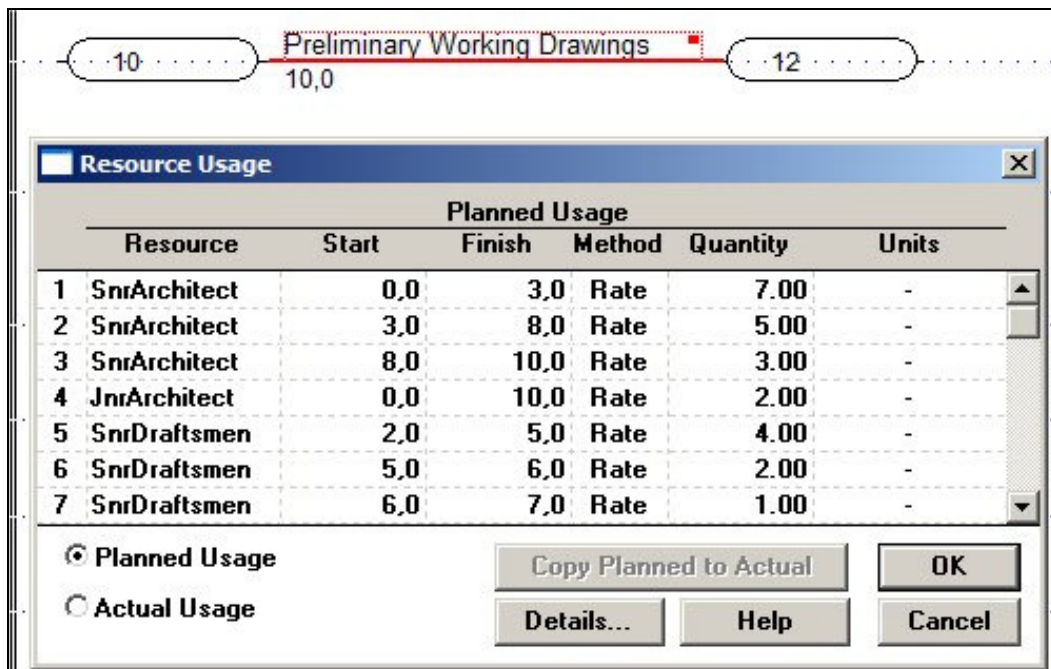

Figure 8: Resources Allocated to an Activity

Figure 9: Complex Resource Input

In Figure 8: Four resources are shown, three in complex format. The fourth (Junior Architect) is shown as a simple resource at a constant rate throughout the duration of the

activity / task. For complex resources it is necessary to specify the quantity required, the start time and finish time of the requirement. This is shown in Figure 9.

Another method of assigning resource requirements for an activity / task is in the form of Work Content or Level of Effort. A work content resource is one where the resource requirement specification is not dependent on a fixed duration for the activity / task. The resource requirement is specified as an aggregate resource allocation (for example, in man-days, with the duration of the activity left unspecified. During resource allocation, the activity duration by the software according to how the available resources were allocated.

The method by which the resource is allocated is by specifying a minimum, preferred and maximum value either for the requirement level or for the activity / task duration. For example, an activity consists of 75 drawings; one draftsman can produce 5 drawings per day, and hence the work content resource requirement for the activity / task is 15 person days. Generally, the user would like three people to work on these drawings, but is prepared to have five people working the activity / task for some of the time if this is necessary. Hence the requirement levels would be specified as follows:-

1. Minimum Level: 1 Draftsman
2. Preferred Level 3 Draftsmen
3. Maximum Level 5 Draftsmen

The activity / task would be scheduled by resource allocation within these limits. Alternatively, instead of specifying requirement levels, values may be specified for the activity duration. The user may decide that the drawings should be completed in 15 days, it must not take longer than 25 days, and the minimum duration is 3 days. In this case the durations would be specified as follows:-

1. Minimum Duration   3 days
2. Preferred Duration   15 days
3. Maximum Duration   25 days

The activity / task would be scheduled by resource allocation so that it is worked within these limits with draftsmen being allocated to drawings as necessary throughout the scheduled duration.

It is important to point out that these three specified durations should not be confused with the standard three-time estimates for activity / task duration. Work Content durations are not calculated down into an "expected Time"

Another method of specifying resource requirements is by giving each activity / task a total amount of required resource required. The amount of resource required is entered as a Total Quantity Allocation then a specific amount of work time is spread evenly over the duration. As a result, no matter how much the duration changes, the overall allocation does not - it is constant.

When an activity is being worked, it is possible that a particular resource which has been specified as being required is not available; although there is an equally good substitute which is available and which may be used instead. Micro Planner X-Pert utilises a system called Group Resources to provide the ability of substitution by program in order to keep an activity / task working. A Group Resource has a code and a name just like any other resource but it is actually a just list of resources which are members of that group. A maximum of twenty resources may be specified in a group, the most efficient substitute is located at the top of the list with the least efficient at the bottom of the list. Of course a

substitute may not have exactly the same set of skills to perform the work and this is taken into account by the use of an efficiency factor.

The substitute resource in some instances may not be available; an alternative to the substitute may be specified. This facility nests to a level of 19 alternatives in groups. Performance or productivity factors either greater or lesser than the original may be expressed for each alternative.

TOTAL RESOURCES AVAILABLE

To carry out resource analysis and scheduling the availability of each resource required by the project plan must be specified. Up to 20 changes of availability may be specified, if overtime can be worked or additional sub-contracting facilities can be made available, then this additional availability is input as a Threshold Limit. Thresholds permit smoother scheduling in cases of limited resource being available, which if they were not available would or could result in an uneven loading of certain critical resources.

MANAGEMENT CONSTRAINTS

Management impositions are nearly always in the form of Time Constraints, which may or may not be possible to meet within resource constraints. The most common time constraint is that the activity / task may start no earlier than a specific time or finish no later than a specific time. These times are known as imposed Times (Dates), they are utilised in the forward and backward passes in Time Analysis.

Depending on, which is the maximum of the computed earliest start time and the Imposed Earliest Start Time, the software may have appear to have ignored an Earliest Start Impose Time should it prove to be earlier than the forward pass Earliest Start Time. The reverse is case for the Latest Finish Time and Imposed Latest Finish Time on the backward pass where the minimum value is taken.

It may be the case that the Imposed Earliest Start Time is the maximum and thus it is used in the forward calculations. Resource Analysis takes no notice of the Imposed Times other than the impact already made on the Time Analysis results.

In the event that the Imposed Times are not satisfactory the Immovable Times in the form of Fixed Start and Fixed Finish may be specified for both Start and Finish Times. If the Fixed Start time cannot be met in the forward pass then all subsequent Total Floats will have no significance in Time Analysis as they cannot be guaranteed with Fix Times.

ACTIVITY PROPERTIES

In addition to specifying resource requirements for each activity / task in the network, certain properties can be assigned to it. These activity properties are used by resource allocation so that it will produce a schedule which wills the specific requirements of the user. These properties are ignored by Time Analysis and Resource Aggregation. The properties are outlined below:-

1. When resource analysis is carried out, it may be possible to produce a shorter schedule by splitting activities /tasks into two or more discrete parts. If an activity is competing for a scarce resource; activity splitting permits resource allocation to take advantage of short periods of time when the resources are available even though

periods are less than the activity duration. Thus, if activities are split, resource allocation may be able to produce a shorter overall time for the project and thus reduce the time or which available resources will be unused.

2. If splitting an activity / task is unacceptable; for example, continuous concrete pouring, then it may be specified as a "Non-Split" Activity. A "Non-Split" activity is defined as being worked continuously during normal working time as specified by the activity's calendar and holiday tables

3. An activity / task may be stated as splittable if its schedule can be interrupted during normal working time. However, this may lead to excessive splitting in the case of severe resource shortages. The splittability may be controlled by specifying one or other of the following options:-
   a. The maximum number of sections into which an activity may be split;
   b. The minimum duration which must be scheduled without interruption; this value is known as the minimum split duration
   c. The period that must be scheduled without interruption before the first split is made, this value is known as the 'Force Start Duration'
   d. The period that must be scheduled without interruption at the end of the activity,/tasks is known as the 'Force Finish Duration'

4. In certain cases when an activity / task has been scheduled, the succeeding dependent activity must be schedule to start immediately the preceding activity has been finished, this is known as either a "Tied Activity" or a "Consecutive Activity". In the event of insufficient resources being available to force the tied activity to commence, it will cause a resource overload, even though the schedule analysis is "Resource Limited".

5. In the case where Resource Analysis has to determine whether an activity / task is more or less urgent than other activities which may be scheduled at this time, it will be necessary to define an "Activity Priority" In the case of Micro Planner X-Pert the activity priority range is -10 to +10. Normally the Activity Priority cell is null and as such the Resource Analysis will assume the value to be "zero". In those cases where the cell is not null then Resource Analysis will consider the activity / task with a higher priority before a lower one.

RESOURCE ANALYSIS

Various forms of resource analysis are available, the most commonly used are:-

1. a)   Aggregation by earliest start date
   b)   Aggregation by latest start date
2.   Resource Limited Resource Allocation
3.   Deadline (or Time) Limited Resource Allocation

To illustrate the principles of Resource Analysis a small example will be described. Consider the following small network, Figure 10, where only a single resource will be used, with an availability of four persons.
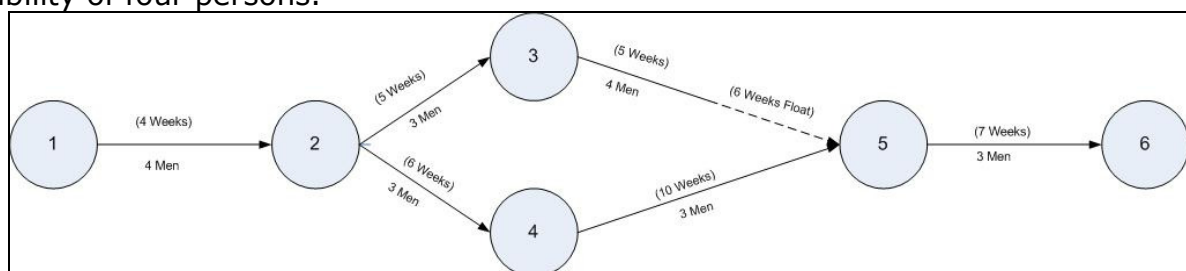

Figure 10

AGGREGATION BY EARLIEST START DATE

This analysis causes all activities / tasks to be scheduled at their earliest possible dates regardless of the resource levels available to the project. This provides a theoretical projection of the resources needed to meet the end date calculated by Time Analysis. This kind of schedule will yield an inflationary cost curve, since all work is scheduled to be carried out earlier than is really necessary or desirable. However, the risk of failing to meet the scheduled completion date is minimal.

The histogram of Resource Aggregation (Figure 11) shows an uneven and impractical load pattern. If management is uncertain of what resources availability levels to input into the software when a project is in the first stages of being built, then the aggregation histogram or table can be of benefit. It shows the maximum and minimum levels from which an average level usually can be deduced.

Figure 11 – Resource Aggregation Earliest Histogram

AGGREGATION BY LATEST START DATE

This analysis causes all activities / tasks to be scheduled at their latest possible without actually delaying the project completion date. Again as in aggregation by earliest start date and resources available to the project are not taken into account.
As a result of delaying all activities / tasks to their latest possible start dates they become critical, that is, no float is available and thus there is a high degree of risk in not being able to meet the scheduled completion date. Naturally the cost outlay is minimal, though the resultant load patter as indicated in Figure 12 would not be unacceptable.

Figure 12– Resource Aggregation Latest Histogram

RESOURCE LIMITED ALLOCATION

Between the two extremes of earliest and latest start dates, a load pattern can be found which fulfils the requirements of management. The resource limit allocation analysis within the software schedules activities / tasks so that the levels of availability are never exceeded. Should there be insufficient resources available then the completion date must be delayed. This process of ensuring levels are not exceeded can be calculated manually if only one or two resources are to be considered. However, more resources are allocated to the various activities / tasks in a network than that and the numerous possible schedules that are obtainable is completely beyond manual methods of calculation if a satisfactory schedule is required. In Figure 13 the histogram for the resource limited analysis shows the scheduled completion date to be delayed by eight weeks.

Figure 13 – Resource Limited Resource Analysis
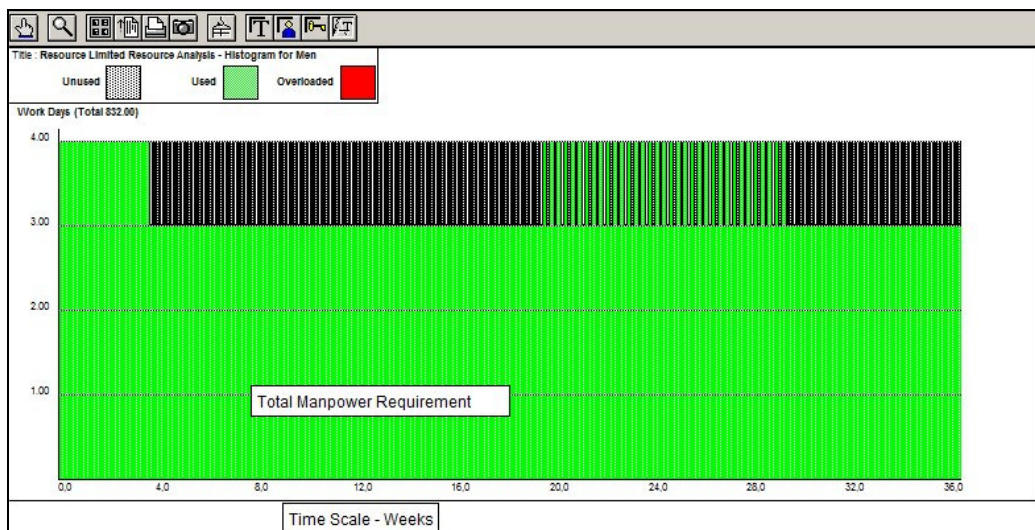
As only one resource is being used in this example not all facilities of resource analysis are being illustrated. One such facility is the splitting of activities / tasks to obtain a better schedule. This is only done when resource limits are extremely tight. Similarly two activities may be scheduled non-consecutively. If technical and practical considerations demand it, an activity / task may be designated as non-splittable or to be scheduled consecutively. These of course place restrictions on the software and if used unwisely can have a worsening affect on the scheduling process than was requested.

DEADLINE LIMIT RESOURCE ALLOCATION

In this analysis activities are scheduled to ensure that the scheduled project completion date is kept, even though certain resources may overload to do it. Normally time limit (deadline) resource allocation is carried out by most companies as most projects have critical completion dates. Figure 14 illustrates a Deadline Limit Resource Allocation histogram. As can be seen an overload occurs from weeks 10 until 19 due to the shortage of resource and the need to maintain the schedule

Figure 14 – Deadline Limit Resource Allocation
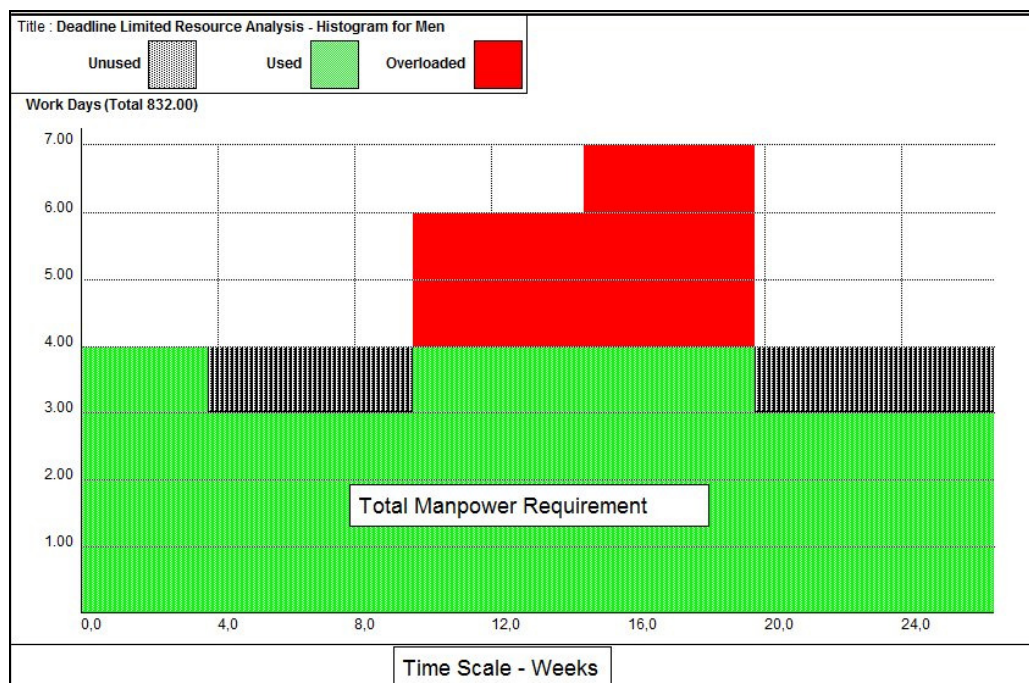
The above histograms have all been produced by Micro Planner X-Pert, different software produces different reports

COMPUTER RESOURCE SCHEDULING TECHNIQUES

Most PC base software currently available, use one of two basic methods to satisfy the requisite allocation, either the "Serial" or "Parallel" method. These are heuristic methods designed to give good but not necessarily optimal solutions. There are algorithmic techniques such as "Linear Programming", which were once available on mainframe software and provided optimal solutions. LP, however, is an expensive method to use as it requires reasonably large computing resources to provide the solution in a rapid timeframe we are used to with PCs'.

Another major problem in using LP techniques is that critical path networks are dynamic, this is due to client changes, weather problems, and corporate priorities change over time. Thus the "perfectly balanced" LP solution is obsolesced very rapidly to be of use. Research

carried out both in Australia and the UK shows no serious use is made of LP or indeed any other algorithmic method for the management of projects.

In the "Serial" method of allocation, a list is made of all the activities / tasks is made, sorted into some order, such as Total Float within Earliest Finish Time. This list is then the basis of allocating resources, the first activity/ task is considered and the required resources allocated to it and the amount is subtracted from the availability originally made available. The second activity is now considered and it too allocated resources, the amount being deducted from the remainder after the first activity was allocated this then is repeated throughout the list. Should an activity require a resource which is fully utilised by an earlier activity, it has to wait until the earlier activity has finished with that resource.

The "Parallel" method works through the project and for one time period at a time selects those activities / Tasks available for scheduling which can use a given resource. It then sorts the activities in order of priority; for example, Earliest Start Time major, Total Float minor and a priority if supplied by the planner. Resources are then allocated to those activities / tasks with the highest priority. If there are insufficient resources to commence an activity, those activities with a lower priority are examined in case they can utilise the remaining resource. If the start of an activity is delayed because it cannot be allocated a resource due to a shortage; it has its Earliest Start time increased and its Total Float decreased. The network is examined to see if the following activities have to be adjusted

MULTI-PROJECT RESOURCE SCHEDULING

So far all that has been discussed has concerned the implementation of a single project. In any organisation many projects are being executed and planned at any point of time. If only some projects are run as single critical path networks it is very difficult to know exactly the position of each project in relation with each other. Therefore it is necessary to consider all projects in the organisation when implementing critical path network planning. This process of consideration is known as multi-project resource scheduling, it may also be known by some companies as Portfolio Management.

The expressions "Project" and "Multi-Project" are subject to various interpretations. To avoid any possible misunderstanding with regard to these expressions with respect to Micro Planner X-Pert, the meanings are as follows:-

> "Project" – a project is considered to be an entity. It is the largest unit which the software can consider at   any one time

Because the requirement to schedule all the projects in the organisation needs common resources they must be defined as sub-projects. The project (as far as Micro Planner is concerned) is all the work. Thus as an extreme case the entire organisation is considered to be a project. This concept of planning is known as multi-project scheduling

The transition from single to multi- project planning is relatively simple with the aid of computer software. As it is well known the use of computers makes the handling and manipulation of the data far more readily than otherwise. Also the software offers so many facilities for planning and simulation that once a course of action has been decided upon the results are available in a very short time to meet most management requirements. For example, by using different resource availabilities with variable use of decision tables, many different schedules can be produced in the same run. These will show the results of either the resource limit or the time limit implications upon the data. Management must still make decisions whether to accept or reject or modify such schedules by inputting amendments or modifications to the network. It is not unusual for complete acceptance of initial outputs for the schedule can be so easily changed by modifying one variable, unless some simulation of the effects of variable input criteria has been executed.

There are two common methods of scheduling multiple projects as follows:

     a) By scheduling each project successively against a residual pattern of resource availability;

     b) By scheduling all projects simultaneously against total resource availability.

Method a), residual resourcing is not really suited for efficient multiple project scheduling as the priority ruling is by individual project. The first project to be scheduled has automatic call on resources that are available throughout the working life of it. The next project loaded has second call on the resources; therefore should the first project be using similar resources the second can be extensively delayed and so on. This method is virtually a manual method and is inefficient in utilisation of resources.

The best method is undoubtedly simultaneous loading of all projects. This approach of scheduling is based upon activity priority (rather than project priority as in method a)). Activities/ Tasks are scheduled time step by time step and the decision whether to schedule or delay activity depends on several factors, for instance, the latest finish date, float values in various priority relationships. It is also possible to input an optional priority on a activity / task for consideration during the scheduling phase. The actual scheduling is carried out by means of decision tables which can be used separately or in conjunction with each other.

Defining and Using Resource Analysis for Scheduling Resources

Resource Analysis is the process by which *Micro Planner* examines the availability of resources and figures out when operations should be scheduled to work within that availability. During this process, the analysis tends to level out the usage of resources.

Resource Analysis produces a schedule of dates for every operation in the project showing when they should start and finish and also produces totals for the usage of resources throughout the project.

The following examines how Resource Analysis works and how you can control and operate it.

As has already been stated previously above about Resource Analysis, you will find that it is possible to specify a method of analysis – **Deadline Critical –** which overloads resources in preference to delaying deadline dates.

However, this type of analysis can be partially overridden by imposing a limit or *threshold* over which the resource may not be overloaded.

Bear in mind that if a Deadline Critical Analysis reaches a threshold; the compulsion to meet existing deadlines is replaced by a new priority – not to overload the resource any further. At this point, *Micro Planner* avoids exceeding the threshold by switching to another type of analysis – **Resource Critical –** which delays operations instead. This means that you may kick off with an analysis which does not delay the project but, if a threshold is encountered, end up with another type of analysis which does!

A threshold quantity is preset to blank – meaning there is an unlimited (or infinite) threshold. If you want to bring a threshold into force, then a value greater than that which has been specified in the availability record must be entered.

Resource Analysis - Deadline Critical v Resource Critical

Micro Planner X-Pert™ has two main forms of resource analysis - Deadline Critical and Resource Critical. Both types of analysis attempt to smooth the projects resource requirements by bulldozing the resource requirement "humps" into the available "hollows" caused but some operations having float available. The difference comes when the smoothing cannot resolve all of the problems within the overall project time frame and resource availability.

Deadline Critical resource analysis (time critical) will maintain project deadlines and overload the resources. Resource Critical resource analysis will delay the project completion until sufficient resources are available.

Resource Analysis Method

The following example demonstrates the basic principals used by Micro Planner X-Pert™ to smooth resource demands. In a real project it may be dealing with up to 250 resources on several thousand tasks and with a maximum of resources allocated to each task.
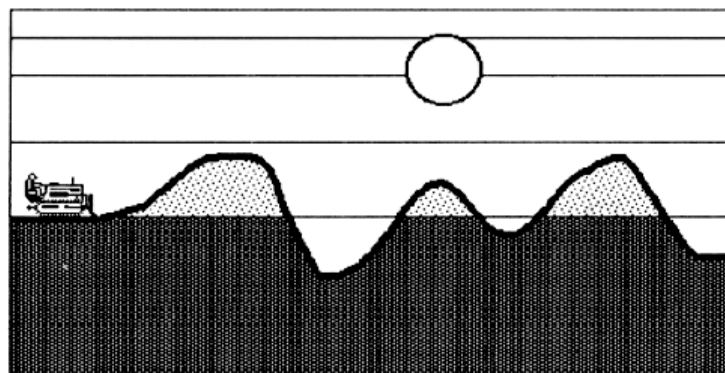
Resource Analysis Process

The analysis starts with all of the operations scheduled on their early start dates and a very inefficient use of resources.

On Day 1, Operation "D" (critical) and "A" (least float) grab the four available resources, "B" and "C" are delayed. On Day 2, "C" and "A" have the same float, but Micro Planner X-Pert™ will stay with the existing allocations to avoid too many splits. By Day 3, "C" has less float than "A" and takes the resource, splitting "A". The status quo is maintained for Day 4 when "C" and "D" are completed and the resources transferred to "A" and "B".
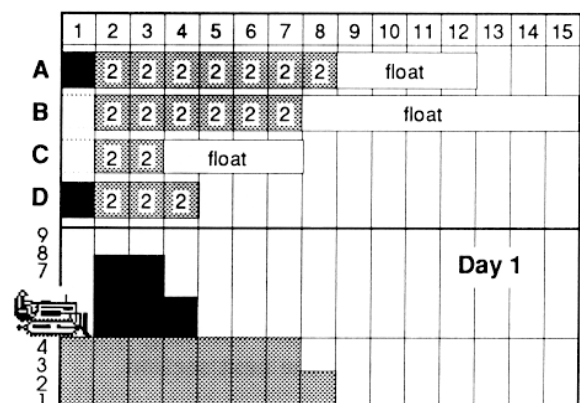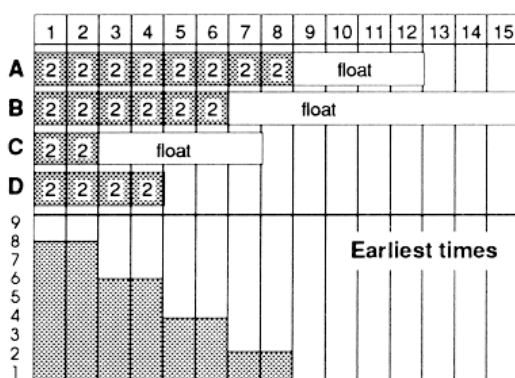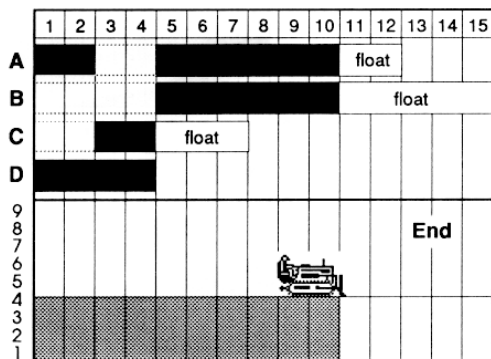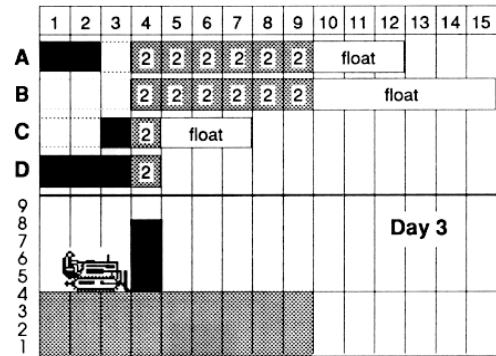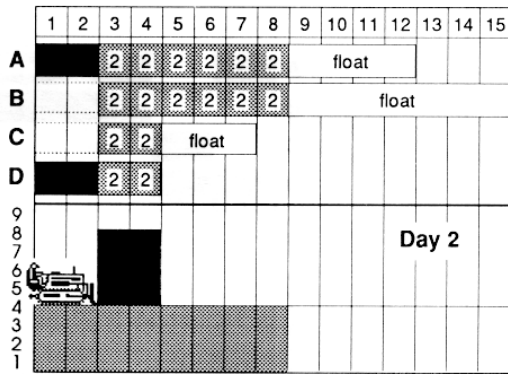
Using Decision Tables to Schedule Resources in a Multi-Project Environment

To schedule a project, a program simulates the project time-period by time –period. For each time period the calculation has three broad phases.

1. A sort of the activities which are free to proceed in order of importance. (An activity is free to proceed if all activities immediately in front of it in the network have been allocated resources. Importance is determined by the *Practical Priority* calculated by the program and the *optional priority* (if any) specified by the user).
2. The *allocation* of available resources to some of these activities, considering them in order of importance.
3. The elimination of activities whose resources requirements have been totally satisfied and the consequent freeing of subsequent activities.

During phase 2, the program scans a list of activities that are competing for the resources available on the time period in question. For each activity the program may decide:

1. To allocate to the activity the resources it requires (which is then subtracted from the total available for the time period)

2. To delay the activity, which will make it more critical, since its total float will decrease

In order to make the decision, the program considers four aspects of the activity in its current state:

1. RESOURCES. If the activity were scheduled would there be enough resources?

   Note: Some of the resources available on this time period have already been allocated to more important activities
   One of three answers is possible:
   a. Enough is available at normal level
   b. Enough is available if the threshold level is used
   c. There is not enough even with threshold resources

2 TIME. What is the time status of the activity? Again there are three possible answers:
   a. Not critical – as the activity stands at the moment it will not delay the project end date beyond what is acceptable
   b. Critical at the first level – the activity has already been delayed so that the preferred end date of the project will not be met, and the project will finish in threshold time
   c. Critical at the second level – the activity has already been delayed so that the final end date of the project will not be met, even using threshold time

3 RESCHEDULING FACTOR. If the activity under consideration cannot be scheduled in this time period, what is the amount of the activity previously scheduled that will now have to be unscheduled? If the activity is splittable, or if it is not scheduled to commence before the time-period under consideration, the answer is zero; but if the activity is designated non-split and (for example) 10 time periods have already been scheduled then the answer is 10, since to keep it in one piece without working on the time-period in question, the program must attempt to reschedule the entire activity starting at this time-period. In the case of an activity with a minimum split the program calculates the smallest amount to be unscheduled without breaking the minimum split requirements

   This rescheduling factor is divided into four categories whose limits are:

   (a)   0 periods
   (b)   1 to 4 periods
   (c)   5 to 10 periods
   (d)   11 periods or more

4 DELAY FACTOR. Assuming the rescheduling factor calculated in 3 was incurred, what would be the time status of the activity?

   (a)   Not Critical
   (b)   Critical at the first level
   (c)   Critical at the second level

		Rescheduling Factor	0 Periods			1 to 4 Periods			5 to 10 Periods			11 or More Periods		
Resource	Delay Factor Time		NC	C 1st Lvl	C 2nd Lvl	NC	C 1st Lvl	C 2nd Lvl	NC	C 1st Lvl	C 2nd, Lvl	NC	C 1st Lvl	C 2nd, Lvl
Enough at Normal Level	NC		S	S	S	S	S	S	S	S	S	S	S	S
	C 1st ,Lvl		S	S	S	S	S	S	S	S	S	S	S	S
	C 2nd ,Lvl		S	S	S	S	S	S	S	S	S	S	S	S
Enough at Threshold Level	NC		D1	D1	S	D1	D1*	S	D1	S	S	D1	S	S
	C 1st ,Lvl		D1	D1	S	D1	D1	S	D1	S	S	D1	S^	S
	C 2nd ,Lvl		D1	D1	S	D1	D1	S	D1	D1	S	D1	D1	D
Not Enough	NC		D1	D1	D1	D1	D1	D1	D1	D1	D1	D1	D1	D1
	C 1st ,Lvl		D1	D1	D1	D1	D1	D1	D1	D1	D1	D1	D1	D1
	C 2nd ,Lvl		D1	D1	D1	D1	D1	D1	D1	D1	D1	D1	D1	D1

Table 5 — Allocation – Less Restricted Threshold

S = Schedule the Activity

D1 = Delay the Activity without violating the Non-Split Rules

C = Critical   L = Level   NC = Not Critical

* = If an Activity is not critical and requires threshold resource to be worked and will be delayed not more that 4 periods if not worked today, and will then be critical at the first level, then delay it

^ = If an Activity is critical at the first level, and requires threshold resources to be worked, and will delayed more than 11 periods if not worked today and will then be critical at the first level, then schedule it

The number of combinations of possible answers to those questions is 108 (3 x 3 x 4 x 3). The decision table for a particular run has one box for each case and each box contains

(a)   S = Schedule the Activity, or

(b)   D1 = Delay the Activity without violating the non-split rules or

(c)   D2 = Split the Activity whether or not it is splittable. Hence if D2 is never used, the non-split rules will never be violated, but it may pay in some circumstances to use D2 to avoid a very untidy scheduled

Details of Standard Decision Tables

Nine standard tables were available in ICL 1900 Series PERT, their details are as follows
1. Aggregation at PERT TIME earliest dates
2. Aggregation at PERT TIME latest dates
3. Resource Limited Schedule – no use of threshold resource
4. Resource Limited Schedule – threshold resources used to avoid extending threshold time
5. Resource Limited Schedule – threshold resource used to avoid extending threshold time and long delays due to unscheduling
6. Experimental Table
7. Time Limited Schedule – threshold time used to avoid extending resource. Splitting of non-split activities to avoid exceptionally long delays
8. Time Limited Schedule – threshold time use to avoid extending threshold resource
9. Time Limited Schedule – no use of threshold time

Micro Planner X-Pert for Windows has four built in decision tables, which may be modified by threshold resources. These tables are
1. Resource Aggregation at PET TIME earliest dates
2. Resource Aggregation at PERT TIME latest dates
3. Deadline Critical Resource Analysis equivalent to ICL Decision Table 9
4. Resource Critical Resource Analysis equivalent to ICL Decision Table 3

When Threshold resources have been specified then X-Pert Decision Table 4 is the equivalent of ICL Decision Table 4 and X-Pert Decision Table 3 is the equivalent of ICL Decision Table 7

Comparative Resource Scheduling Using Various Software Packages

Introduction

The premise of the following is to illustrate that Resource Scheduling is a most important part of the Project Planner & Scheduler's armory, but is not often used as much as it should be. It appears to be generally accepted that Resource Loaded projects are too hard to operate and that the results are quite often not what would be expected and that there are too many conflicting attributes in particular software to select without understanding how they relate to each other.

It is my contention that there is never an occasion where a project is analyzed without the use of resources otherwise the results which are produced running Time Analysis only assume unlimited resources are available to the project.

The logical output you expect from any planning/scheduling package, ie the whole of the available time to be utilized with some resource overload is to be expected, and that any target completion dates are not violated in the production of the results. Without such a stated objective one can assume that all the results generated from a software package are valid, even if not what one intuitively expects.

Which as we all well know is not true but how do different project management Software packages process the same data and what are the variations in the results obtained? This then is the premise of this paper, where a basic model has been developed, how, then, do various software packages handle this model.

A simple critical path network of four tasks and two milestones was created and a single resourced was allocated to each of the four tasks. The network is shown in Exhibit 1, three of the tasks have ten day duration and the other has duration of 30 days, giving a resource total of 480 hours of effort. The finish milestone has an imposed constraint date of 31st August 2007 (Target, Finish On or before).

Exhibit 1 – Sample Network
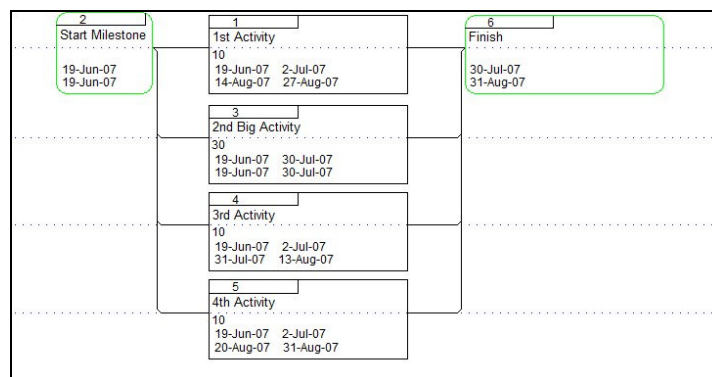
The sample network has a start date of 19th Jun 2007; running time analysis gives a completion date of 30th July 2007. Tasks 1, Task 3 and Task 4 each have twenty days Total Float. The total number of man hours of work is 480, i.e. 60 days x 8 hours per day. The dates shown in the task boxes in Exhibit 1 are the Earliest Start and Earliest Finish on the first line and the Resource Start and Resource Finish on the second line

Running resource analysis manually to the earliest end date of 30th July 2007, indicates that there will be an over allocation of 230 hours of work.

The problem to be solved is to determine how many extra people are required to be added to the project to execute the actual amount of work and if extra cannot be obtained what will the delay be

after the client's imposed finish date 31st August 2007? Or how much overload will occur in maintaining the imposed date of 31st August 2007?

This data was then input into three different Project Management Software Applications, these were

1. Primavera V3 Enterprise
2. Deltek OPP V3
3. Micro Planner X-Pert for Windows V3.12

1. Primavera 3 Enterprise

The same simple project was input into Primavera V3.Enterprise. The Finish milestone has a 31 Aug 07 constraint (Finish on or before). The total calendar duration is 54 days.

Establishing the basic model by running Time Analysis only, using the early dates, and with no leveling; logic states you would finish on the 30 Jul 07, and the resource scheduling would over allocate 230 hours of work out of the 480 hours. (That is 60 work days of 8 hours each), and no total float used or imposed dates considered. Exhibit 2 shows the resource histogram with the overload as expected and the Gantt chart shows that the tasks are scheduled at their early dates. Note the summary task is 30 days, which indicates that the imposed end date of 31st August 2007 has not been considered in the analysis. The analysis was a "straight out of the box" schedule, which does not provide the optimal answer

Exhibit 2 – Basic Default Resource Leveling
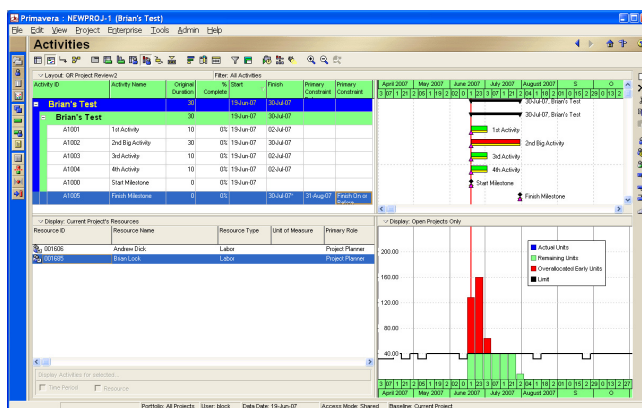
An analysis running Resources and Leveling was initiated, but (Level resources only within Activity Total Float) option was not checked. The Leveling priority was set at Early Finish and Preserve Early and Schedule Dates was checked. Note task 2 finishes on the 11 Sep 07pm, 7 days after the constraint date. See Exhibit 3 for the resource histogram and Gantt chart and schedule. This is in spite of not wanting the schedule to be schedule past 31st August 2007. The summary task is now shown as 61 days.

### Exhibit 3 – Resource Leveling – Early Finish
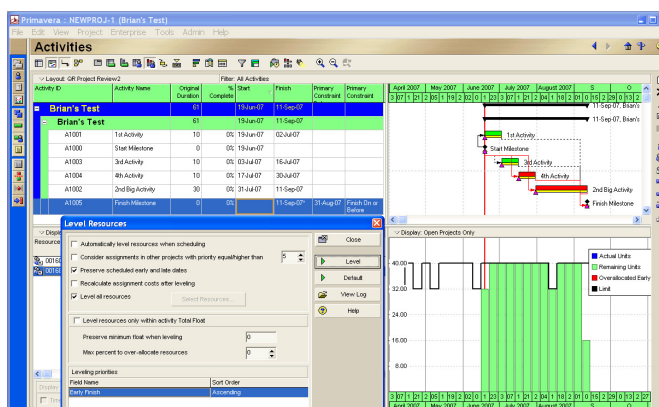
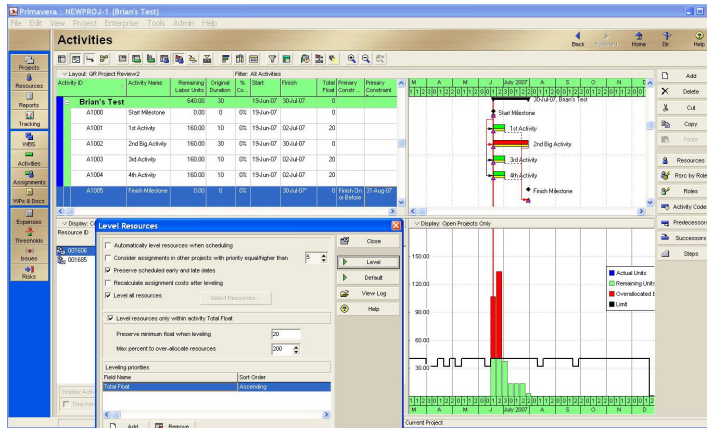A second analysis was carried out with Resources and Leveling applied, but (Level resources only within Activity Total Float) option was not checked. The Leveling priority was set at Early Finish. Note task 2 finishes on the 11 Sep 07, 6 days after the constraint date. See Exhibit 4 for the resource histogram and Gantt chart and schedule. This is in spite of not wanting the schedule to be scheduled past 31st August 2007. However note that there is no overload in the resource schedule. The summary task is now 61 days.

Exhibit 4 – Resource Leveling – Total Float

A third analysis was carried with Resources and Leveling applied, This time (Level resources only within activity Total Float) selected, Leveling priorities set at Total Float, and 0% set at Max % to over allocate resources. As can be seen in Exhibit 5 the resource schedule appears to over allocate 230 hrs (29 Man days), to finish a month early on the 30 Jul 07? Note the summary task is now only 30 days.

Exhibit 5 – Resource Leveling – Total Float – Max % Over Allocate
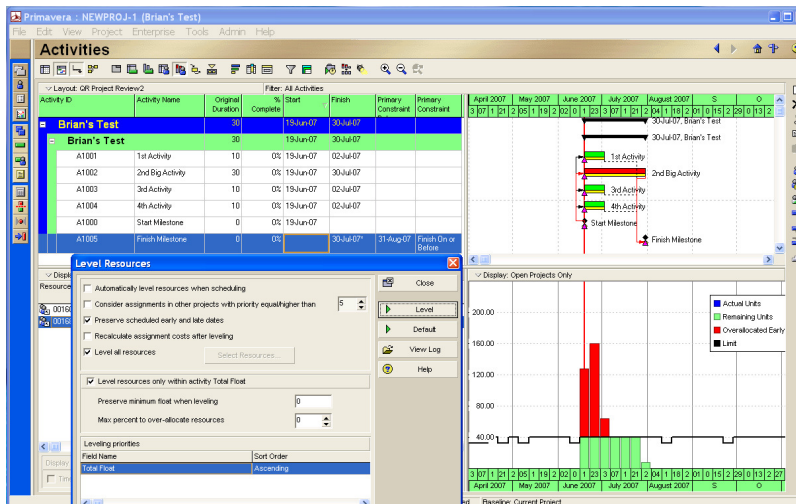
A fourth analysis was carried out (Level resources only within activity Total Float) selected, Total Float Leveling priorities were set, and 200% set at Max % to over allocate resources plus preserve 20 Days of minimum float. The results as observed in Exhibit 6 appears to give same answer as time analysis on early dates and finish a month early on the 30 Jul 07. Note that the summary activity is back to 30 days.

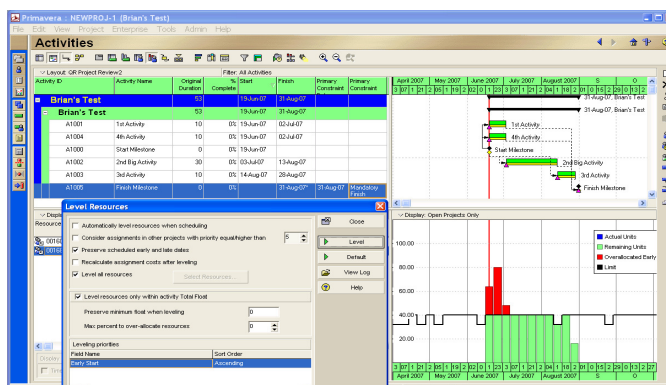**Exhibit 6 – Resource Leveling – Total Float – 200% Max % Over Allocate**

A fifth analysis was carried out (Level resources only within activity Total Float) selected, Total Float Leveling priorities set, and 100% set at Max % to over allocate resources plus preserve 0 days of minimum float. The resource schedule appears to over allocate 47% or 225 hrs of work and finish a month early on the 30 Jul 07 as shown in Exhibit 7. The summary task is still 30 days.

Exhibit 7 – Resource Leveling – Total Float – 100% Max % Over Allocate
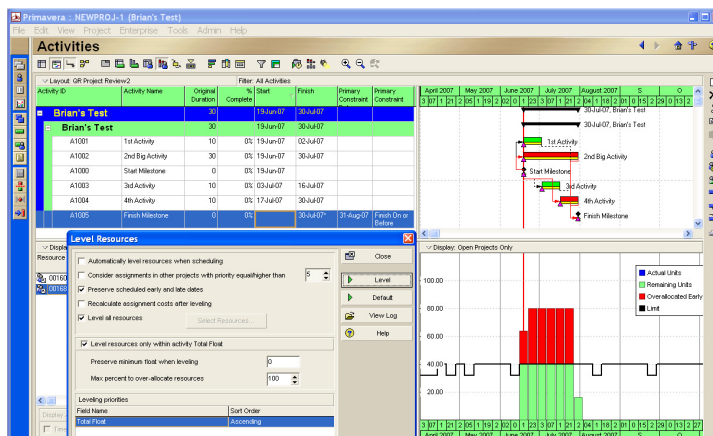
A sixth analysis was detailed where the Finish Milestone constraint was changed to Mandatory Finish (Level resources only within activity Total Float) selected, Early Start Leveling priorities set, and 0% to over allocate plus preserve 0 hours of minimum float. The resource schedule now appears to over allocate early then finish last activity on the 28 Aug 07, wait 3 days then schedule finish milestone as can be seen in Exhibit 8. The summary task is now 53 days.

Exhibit 8 – Resource Leveling – Mandatory Finish – 0% Max % Over Allocate

A seventh analysis was created and the Finish Milestone constraint changed to **Mandatory Finish** (Level resources only within activity Total Float) selected, Total Float Leveling priorities set, and 0% to over allocate plus preserve 0 hours of minimum float. As can be seen from Exhibit 9, the resource scheduling appears to over allocate early for approx 2 weeks then finish last activity on the 28 Aug 07, wait for 3 days then schedule finish milestone. Note the summary task is 53 day
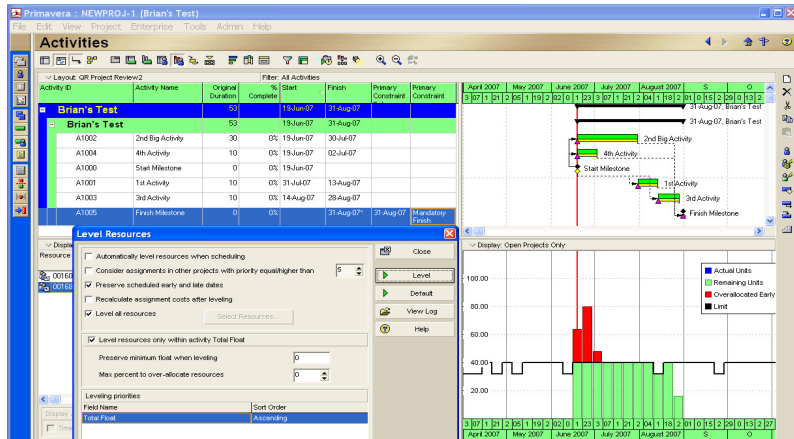

Exhibitt 9 – Resource Leveling – Mandatory Finish – Total Float Leveling Priorities

In observing how Primavera resource schedules it would appear that no matter how the user wants to utilize the Total Float, the tasks are always scheduled too early and where the tasks are delayed by the resource limit, the schedule over runs by seven days past the imposed finish date of 31st August 2007.

2. Deltek Open Plan V 3

The same data was input into Open Plan Professional, the first analysis carried out was the default, i.e. straight out of the box schedule. No parameters were set. As can be seen in Exhibit 10, in the Resource Histogram, the schedule overload occurs at the earliest dates immediately in the first ten days (cyan colour), when the schedule is delayed to the latest start dates, the schedule overload is pushed to the right (red colour). The Resource limited schedule extends the schedule to 10th Sep 2007 (green colour). Note where activities 1,3 and 4 now are scheduled to occur on the timescale.

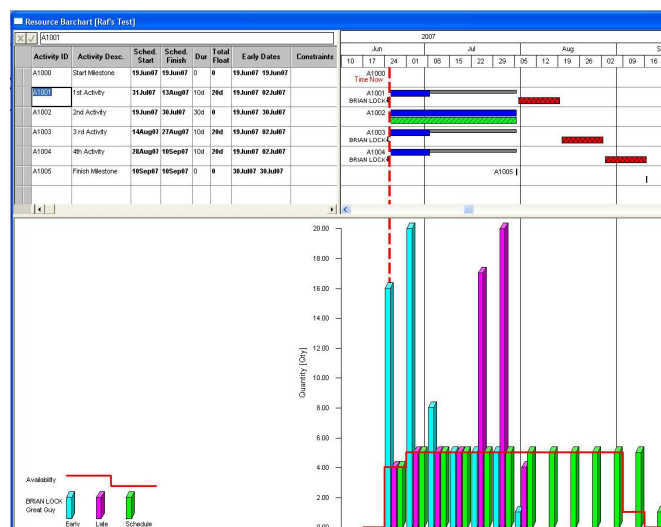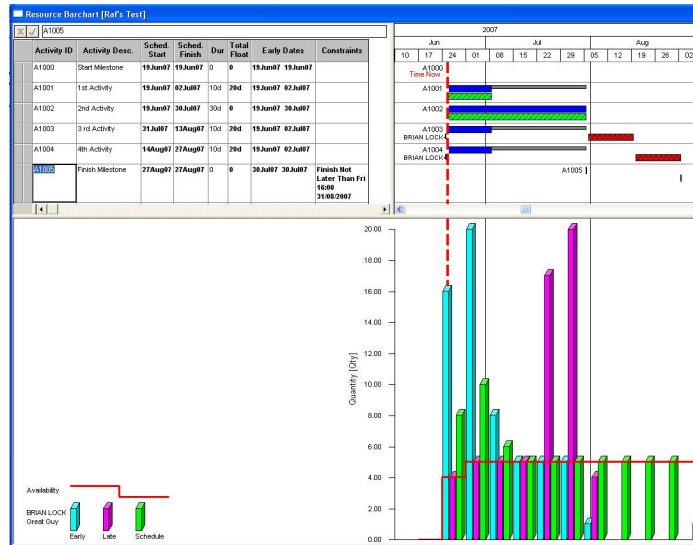**Exhibit 10 – Resource Schedule - No Constraints**

Exhibit 11 - Resource Schedule

Another analysis was run specifying that the schedule should take cognizance of the imposed end date utilizing the earliest start dates for the forward schedule. Activity 2 and Activity 4 were resourced as at the early dates which cause a resource overload, Activity 1 and Activity 3 are delayed until their late dates. The model completes at 31st August 2007 as intended. Exhibit 12 shows the Resource Histogram and where the activities have been scheduled and the Bar Chart shows where on the timescale the activities have been schedule

Exhibit 12– Resource Schedule – Imposed End Date (Earliest)

Another analysis was run specifying that the schedule should take cognizance of the imposed end date utilizing the latest start dates for the forward schedule. Activity 2 and Activity 4 were resourced as at the latest dates which cause a resource overload, Activity 1 and Activity 3 are delayed until their late dates. The model completes at 31st August 2007 as intended. Exhibit 13 shows the Resource Histogram and where the activities have been scheduled and the Bar Chart shows where on the timescale the activities have been scheduled

Exhibit 13 – Resource Schedule – Imposed End Date (Latest)
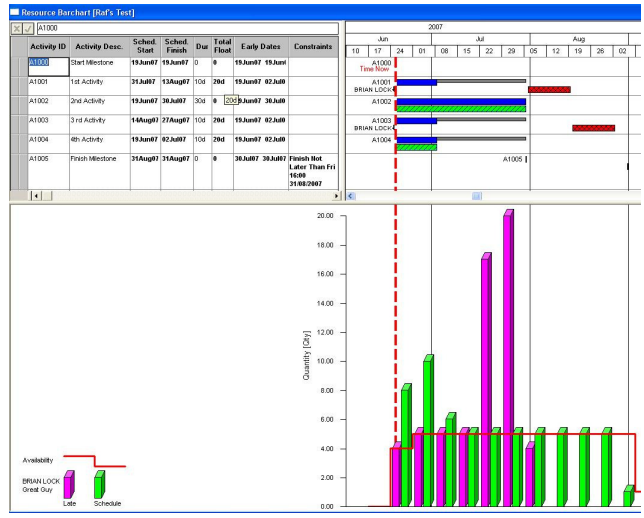

3. Micro Planner X-Pert for Windows V3.12

Having input the data into Micro Planner X-Pert for Windows, a Deadline Critical Resource Analysis was carried out, using the Analysis Controls facility; the default of allowing the resource analysis to split tasks was turned off and the minimum split duration was set to 1 day as shown in Exhibit 14 below:-

Exhibit 14 - Analysis Controls (Non Split)
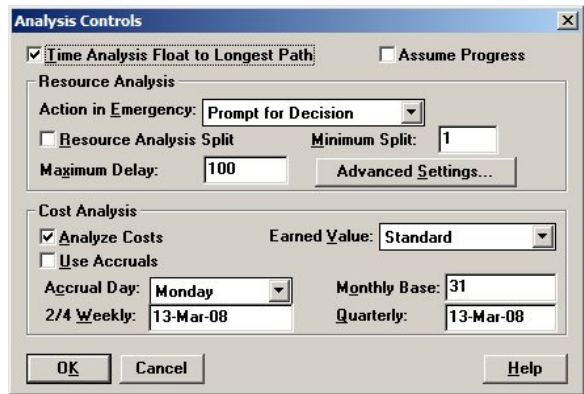
The resource histogram showing the results of the analysis are illustrated in Exhibit 15 below. The allocation of the resource is maintained at the rate of one per day for the first

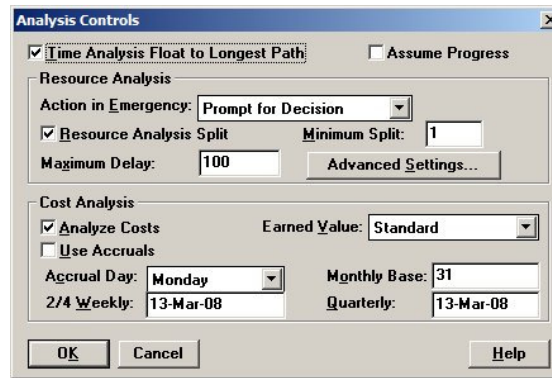**Exhibit 15 – Deadline Critical Resource Analysis - Resource Histogram Non-Split**
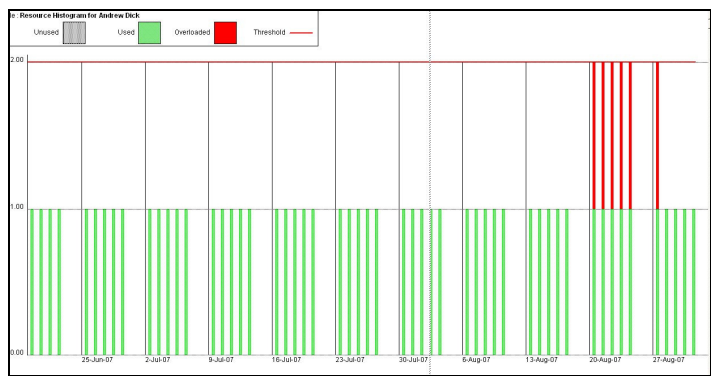
nine weeks until 20th August 2007. Only one additional person for six days is required to complete the tasks by the imposed end date of 31st August 2007; that is 48 hours overload. A Gantt chart showing the analysis of where each task has been allocated in time is shown in Exhibit 16.

Exhibit 16 – Deadline Critical Resource Analysis Gantt Chart – Non Split
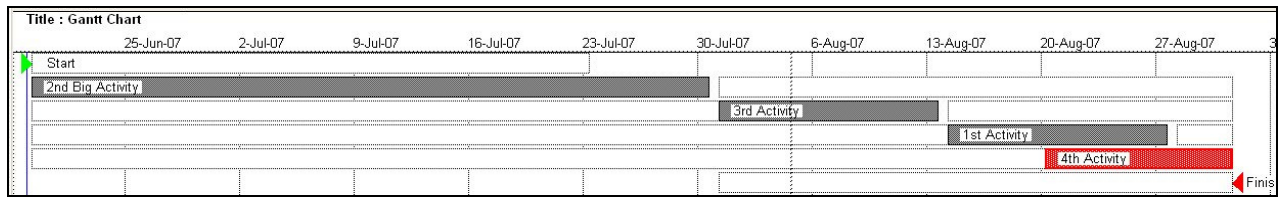
The resource analysis has scheduled Task 2 first as it has the longest duration, then Task 3 is scheduled and then Task 1, but Task 1 was delayed due to the limit of one resource being available. However Task 4 has also been delayed due to the limit of one, but because the analysis type is Deadline, which means the Resource Analysis cannot allow any Task to be delayed past the imposed end date of 31st August 2007, so even though the resource limit is one, Task 4 must be scheduled even though it causes an overload in the resource. This is indicated by the red bar in the histogram. (Exhibit 15)

Exhibit 17 – Analysis Controls (1 Day Split)

A second analysis was carried out which allowed tasks to be split by a minimum of one day (as shown in Exhibit 17) at a time to avoid the resource being overloaded. The results of the Deadline Critical Resource Analysis are shown in Exhibit 18 – Deadline Critical Resource Analysis - Resource Histogram – (1 Day Split)
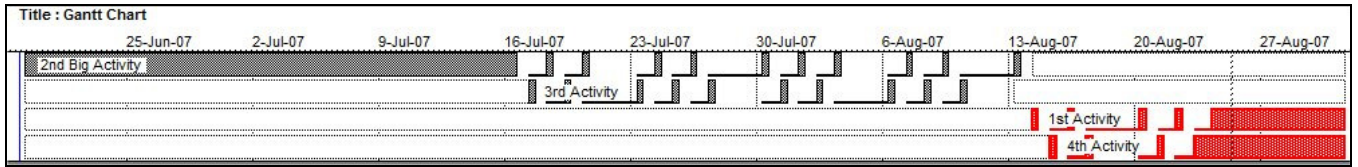
The resource analysis has scheduled Task 2 for twenty days and then it schedules Task 3 which is split between Task 2 which allows the limit to be maintained at one, then Task 1 is scheduled but is also split to allow Task 4 to be scheduled, by which time total float is now running out

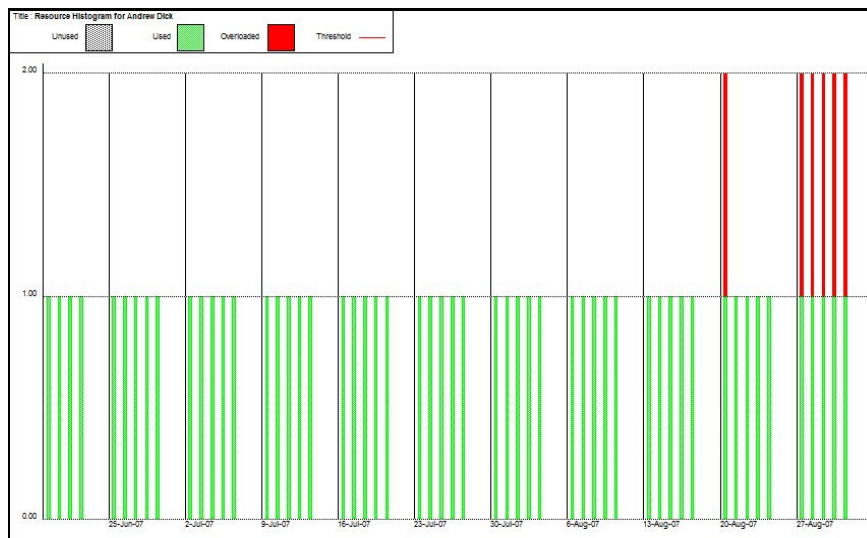**Exhibit 18- Deadline Critical Resource Analysis - Resource Histogram –(1 Day Split)**

31
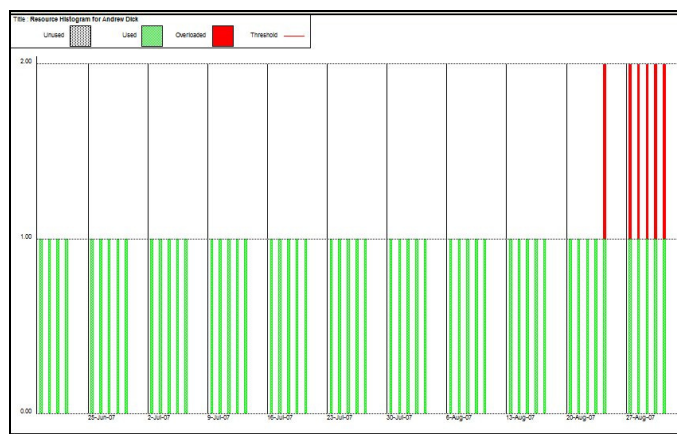
thus the tasks start to become critical, but splitting between the two tasks occurs for five days and because of criticality the two tasks must now be scheduled together into overload, This is indicated by the red bar in the histogram. (Exhibit 18) and can be easily observed in Exhibit 19 – Deadline Critical Resource Analysis Gantt Chart – (1 Day Split). You can see that the resource overload has now been pushed to the imposed end date of 31st August 2007

**Exhibit 19 – Deadline Critical Resource Analysis Gantt Chart – (1 Day Split)**

A third analysis was carried out which limited tasks to be split by a minimum of five days at a time to avoid the resource being overloaded. Task 3 is scheduled to occur after twenty days of the start of Task 2, maintaining the limit of one resource, Task 2 is scheduled for a further five days (as this is the minimum split). Task 3 is then scheduled and is completed. The last five days of Task 2 are then scheduled, all the time the limit of one is being maintained. Task 1 is now scheduled for 6 days and stops for four whilst Task 4 is scheduled. This causes one day where both tasks have to be scheduled together to avoid delaying the project, even though it causes an overload. The four days having elapsed Task 1 no longer has any float and thus has to be scheduled with Task 4 thus causing another overload for five days. The results of the Deadline Critical Resource Analysis are shown in Exhibit 20 – Deadline Critical Resource Analysis – Resource Histogram

Exhibit 20 – Deadline Critical Resource Analysis - Resource Histogram – (5 Day Split)

Histogram – (5 Day Split). The Gantt chart in Exhibit 21 clearly illustrates the schedule of each activity by the resource analysis.

Exhibit 21 – Deadline Critical Resource Analysis Gantt Chart – (5 Day Split)
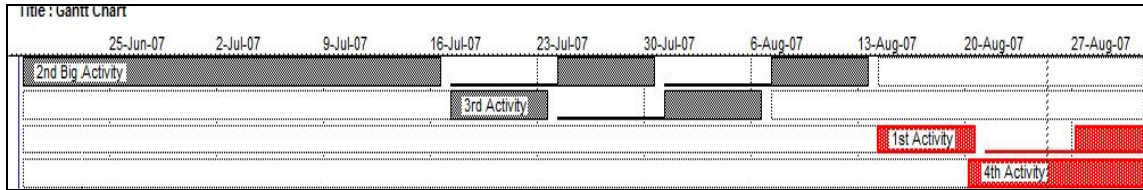
Conclusion

Resource Over-Allocation occurs when activities/tasks are competing for the same resource at the same time. Several techniques can be used together or independently to eliminate or reduce the over-allocation of a resource.
A common technique is to change non-critical activities to critical activities.

The three project management software packages tested in this study provide various resource schedule solutions as described below:

- Considerable knowledge of how to specify the large number of variables and parameters in Primavera was required before producing a reasonable schedule.
  Eight analyses were carried out using the variable parameters without once producing the same result as produced from Micro Planner X-Pert.
  Good knowledge of Open Plan Professional was also required to produce a result that was close to results obtained from Micro Planner X-Pert.

- Neither Primavera nor Open Plan was able to schedule using Resource Analysis (Deadline Critical), which is a standard resource analysis technique found in Micro planner X-Pert

- Micro Planner X-Pert for Windows was the only application that provided an optimal solution "straight from the box"

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Contacting Micro Planning International

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AUS   www.microplanning.com.au

A sample fully operational copy of the X-Pert software can be downloaded from our US and UK sites